"On the Electrical Conductivity of Flames containing Salt Vapours." By HAROLD A. WILSON, B.Sc. (Lond. and Vic.), 1851 Exhibition Scholar. Communicated by Professor J. J. THOMSON, F.R.S. Received March 10,—Read April 27, 1899.

(Abstract.)

The experiments described in this paper were undertaken with the object of following up the analogy between the conductivity of salt vapours and that of Röntgenised gases, and especially of getting some information about the velocities of the ions in the flame itself.

They are to some extent a continuation of the research of which an abstract has already been published in the 'Proceedings of the Royal Society.'*

The paper is divided into the following sections :—

(1) Description of the apparatus for producing the flame.
(2) The relation between the current and E.M.F. in the flame.
(3) The fall of potential between the electrodes.
(4) The ionisation of the salt vapour.
(5) The relative velocities of the ions in the flame.
(6) The relative velocities of the ions in hot air.
(7) Conclusion.

The apparatus used for producing the flame was similar in principle to that used in the investigation referred to above. Carefully regulated supplies of coal gas and air were mixed together along with spray of a salt solution, and the mixture burnt from a brass tube 0·7 cm. in diameter.

The flame thus obtained was steady, and measurements of its conductivity, when a particular salt solution was sprayed, did not differ more than 1 or 2 per cent. on different days. The height of the inner sharply defined green cone was 1·5 cm., and that of the outer cone 7·5 cm.

The current between two gauzes of platinum wire, each 14 cm. in diameter, and placed horizontally one above the other in the flame, was measured for E.M.F.'s up to 800 volts, and with various distances between the gauzes.

The current with a large E.M.F. was found to be independent of the distance between the electrodes when the upper electrode or gauze was positively charged, provided that the distance between the electrodes was not so great that the upper one was in the cooler parts of the flame near its point. When the upper gauze was comparatively

* "The Electrical Conductivity and Luminosity of Flames containing Vaporised Salts," by Arthur Smithells, H. M. Dawson, and H. A. Wilson, 'Roy. Soc. Proc.,' vol. 64, p. 142.

cool the current was much smaller, but if the upper gauze was kept hot by passing a current through it, then the current with a large E.M.F. was independent of the distance between the electrodes, even when the upper electrode was above the point of the flame.

If both of the electrodes were hot, then the current, as the E.M.F. was increased, attained a nearly constant value. Cooling the positive electrode by raising it in the flame caused the current to increase towards this saturation value much more slowly than before, while cooling the negative electrode, the positive one being hot, caused the current to show no sign of arriving at a maximum value. The current was much greater when the negative electrode was hot, and the positive electrode cool, than when the negative electrode was cool, and the positive one hot.

The fall of potential in the flame between the gauzes was examined by putting in an insulated platinum wire, and finding the potential it took up. When both the electrodes were hot, the fall of potential closely resembled that observed in gases at low pressures. That is to say, near each electrode there was a comparatively sudden fall of potential much greater near the negative electrode than near the positive, with a small and nearly uniform gradient in between. If either of the electrodes was cooled, then the fall of potential near that electrode became much greater, and often was nearly equal to the total drop of potential between the electrodes. This effect was usually much more marked in the case of cooling the negative electrode than with the positive electrode.

If the positive electrode was uppermost and somewhat cool, then with small E.M.F.'s practically all the potential fall occurred near to the positive electrode; but if the E.M.F. was sufficiently increased, then a drop of potential appeared at the negative electrode, and with a still greater E.M.F. this became greater than that at the positive electrode, as it is in gases at low pressures.

Some of the results obtained pointed to the conclusion that nearly all the ionisation of the salt vapour takes place at the surfaces of the glowing electrodes, and not throughout the volume of the flame. A variety of experiments were tried to test this view, all of which confirmed its correctness. Thus, with two platinum foil electrodes opposite one another in the flame, no increase in the current between them occurred when a bead of salt was put between them, so that the salt vapour from it passed between them without touching either electrode. If the vapour came in contact with the negative electrode, there was a great increase in the current, and a considerable but smaller increase when it came in contact with the positive electrode.

The relative velocities of the ions of alkali metal salts in the flame were estimated by finding the potential gradient necessary to make the ions travel down the flame against the upward current of gases.

This was done by putting a bead of salt between the two gauze electrodes, and finding what E.M.F. was necessary to produce an increase in the current between the electrodes when the bead was put in.

The potential gradient corresponding to this least E.M.F. was then determined. In this way it was found that the positive ions of salts of Li, Na, K, Rb, and Cs, all have nearly the same velocity in the flame, whilst the negative ions of various salts of these metals also have equal velocities which are about seventeen times as great as the velocities of the positive ions.

The velocity of the positive ions was estimated to be about 60 cm. per second for one volt a cm., and that of the negative ions was about 1000 cm. per second.

The relative velocities of the ions of various salts was also determined in a current of air at about 1000° C., which was obtained by passing the air through a platinum tube 1·3 cm. in diameter, and 50 cm. long, heated in a gas-tube furnace. The method used was exactly analogous to that used in the flame. The ions could be divided into three classes, in each of which all the ions had equal velocities, viz. :—

<table>
<tr><td></td><td>Velocity.</td></tr>
<tr><td>1. Negative ions of salts of Li, Na, K, Rb, Cs, Ca, Sr,
　　and Ba ....</td><td>26·0 cm.-sec.</td></tr>
<tr><td>2. Positive ions of salts of Li, Na, K, Rb, and Cs.........</td><td>7·2　　,,</td></tr>
<tr><td>3. Positive ions of salts of Ca, Sr, and Ba ....</td><td>3·8　　,,</td></tr>
</table>

It thus appears that those ions which in solutions carry equal charges have equal velocities in the gaseous state. This points to the conclusion that the velocity of a gaseous ion in a given medium depends only on its charge. The velocities are less than those calculated for ions consisting of one atom, so that each ion appears to be a cluster of atoms. If we regard this cluster as held together by the charge on it, then it is reasonable to suppose that the size of the cluster will be determined by the charge. Hence those ions having equal charges will be of equal sizes, and consequently of equal masses, since the atoms forming the cluster probably come from the medium rather than from the small quantity of salt present. Consequently they all have the same velocity under similar conditions.

The two main results arrived at in this paper, viz., that the ionisation of the salt vapour in the flame takes place only at the surfaces of the glowing electrodes, and that the velocity of the negative ions in the flame is very much greater than the corresponding velocity of the positive ions, enable the phenomena of unipolar conduction to be very easily explained. For example, if one electrode is much hotter than the other, then if the hot electrode is negative, it will give off negative ions very freely, and there will be a large current; but if the hot

electrode is positive, then the small velocity of the positive ions is not favourable to their being dragged away from the electrode before they can recombine, so that the current is very small unless a very great E.M.F. is applied.

" On a Quartz-thread Gravity Balance." By RICHARD THRELFALL, lately Professor of Physics in the University of Sydney, and JAMES ARTHUR POLLOCK, lately Demonstrator of Physics in the University of Sydney. Communicated by Professor J. J. THOMSON, F.R.S. Received April 11—Read April 27, 1899.

(Abstract.)

The first part of the paper contains an account of the instrument in its present form, an account of the investigations leading up to the form adopted being relegated to an appendix.

The principle of construction is as follows :—A quartz thread (which requires to be prepared with much care) is stretched horizontally between two supports, to which it is soldered. At one end the point of attachment is the centre of a spring of peculiar construction, designed so as to be capable of displacement in the direction of the thread, but incapable of any transverse motion or vibration.

At the other end the thread is attached to the axle of a vernier arm moving over a sextant arc ; by turning the axle the thread may be more or less twisted, the amount of twist being ascertained in terms of the divisions of the sextant arc.

Midway between the two supports the thread is soldered to a short length of fine brass wire, which is adjusted so that the centre of gravity of the wire does not lie immediately above or below the thread, but at some distance from it. The wire forming the " lever " is then rotated about the thread as axis in such a manner that the two halves of the thread are twisted through about three whole turns, and the torsion of the thread is then of such a value that the lever assumes a horizontal position. This adjustment is made by weighting the lever with a small speck of fusible metal. The " balance," which determines the position of the lever with respect to the horizontal plane through the thread, is composed of the earth's gravitational force on the one hand, and the forces of resilience of the twisted thread on the other. Were gravitational force to increase, the centre of gravity of the lever would fall, the end of the lever would move out of its sighted position, and the thread would have to be slightly twisted by the vernier axle in order to bring the lever back to its sighted position.

Differences in the gravitational intensity at different stations are expressed in terms of the amount by which one end of the thread